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BROOKLYN BOTANIC GARDEN

LEAFLETS

SERIES XIV BROOKLYN, N. Y., APRIL 7, 1926 No. 1

HOUSE PLANTS *

It is well to recognize that many difficulties have to be faced before plants can be grown successfully in an ordinary dwelling house, but, by giving careful attention to cultural details these can often be overcome. The hot, dry atmosphere, the fumes of illuminating gas, insufficient light, and great variation in day and night temperature, all tend to make their cultivation a difficult operation. However, in spite of these drawbacks, it is possible to grow a fairly large variety of plants in an ordinary house, and one need not be limited to the ubiquitous India rubber plant. It is among the so-called "foliage" plants that the greatest number of suitable subjects for the purpose under consideration are to be found. The Boston ferns, dracaena, pandanus, aspidistra, and sanseviera are well adapted to withstand adverse conditions. In selecting flowering plants, those should be chosen, as far as possible, which make a large part of their growth out-of-doors. Among this class of plants are the forcing bulbs, such as hyacinths, tulips, crocus, and the well-known azaleas. Primroses and cyclamen will also last a fairly long time in good condition.

The best aspect for the majority of plants is in a window facing south or southwest, as there are comparatively few plants that will grow satisfactorily without abundance of light. If a well-lighted position is not available, one's choice is almost entirely restricted to foliage plants. A bay window on the sunny side of a house will provide almost ideal conditions for a considerable number of plants, and a delightful effect may be obtained by growing them either in pots or in boxes constructed to fit the window.

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* This leaflet is a revised reprint of Number 12, Series III, and Number 7, Series IX.

Temperature is an important factor in the successful cultivation of plants, and violent fluctuations should be avoided as far as possible. If warmth-loving plants are grown in a room which is unheated at night, as often happens, they should be protected in some way during severe weather. This may be done by removing them to a heated room or away from the windows. If this is impossible, they can be protected by covering them at night with paper or other non-conducting material. Bound up with the question of temperature is that of ventilation. Plants object to impure air as much, or more, than human beings; therefore, the room in which they are grown should be ventilated whenever possible, taking care, however, that cold drafts do not blow directly on the plants.

One is frequently asked, "How often must I water my plants?" To this one is compelled to reply, "As often as they need it." There can be no fixed rule as to the quantity and frequency of the application of water to plants; so much depends upon the humidity of the room in which the plants are growing, the nature of the plant, and the capacity of its roots to absorb water. Whenever watering is done it should be done thoroughly so that the earth is wet all through. No further watering is needed until the earth shows signs of drying out, when another application should be given. Thorough watering is most important, otherwise the earth on the surface of the pot may have the appearance of being moist, while an inch or so below the surface it may be dust dry, greatly to the detriment of the plant.

Those living in a city often have difficulty in obtaining a supply of suitable soil for potting purposes, and the best plan in such cases is to obtain from a florist soil ready mixed. The best kind of soil for the majority of house plants is that formed of loam cut from the surface of a meadow, pasture, or lawn. This should be mixed with stable manure in the proportion of three parts of soil to one part of manure, piled in a heap, and left for a year or so in order that the grass roots and manure may decay. Using this as a base, by the addition of leaf mold, peat, or sand, for such plants as need it, we have a soil that makes a suitable potting medium for almost any class of plants.

No definite rule can be laid down as to when plants should be repotted. If they are making vigorous root growth this may be done at almost any time; but, as a general rule, repotting is best done in early spring, just before the plants begin their new growth. Repotting into a larger pot should be done only when the pot is crowded with roots, otherwise harm rather than good will result; indeed, much of the unhealthiness in house plants can be traced directly to attempting to grow them in too large a pot. It sometimes happens that repotting is necessary because there are too *few* roots in the pot rather than too many. This occurs when, through over-watering, the earth becomes sour, and, as a consequence, the roots are unable to maintain themselves in a healthy condition. Plants in this condition should have the soil gently washed from the roots previous to repotting them in fresh, sweet soil. Use pots large enough to contain the roots without crowding them. The new pots should be washed clean and allowed to dry before using. Proper drainage is very important in order that superfluous water may be readily carried off, and this is best obtained by placing a layer of broken pots or coarse ashes over the bottom of the pot. When repotting into a larger pot, the plant should be turned out of the old pot, placed in position and earth filled in around it, tamping the earth down with a piece of lath or something similar, in order that it may come uniformly in firm contact with the roots. Care must be taken not to pot the plant too deeply: the old ball of earth should be covered with about one-fourth inch of soil.

Owing to the lack of facilities for syringing, plants in dwelling houses rapidly become coated with a layer of dust, and this must be removed if they are to be kept in good health. Those plants having large, leathery leaves are best dealt with by washing, using a soft sponge and tepid, soapy water. This process is too tedious an operation in the case of ferns and plants having small leaves, which should be washed by spraying them with water from the faucet or garden hose. Advantage should be taken of warm gentle rain by placing the plants out-of-doors, as they are greatly benefited by this.

The insects most likely to infest house plants are aphids, mealy-bug, scale, and red spider. Aphids can easily be exterminated by spraying, or by dipping them in a nicotine solution; or an insecticide can be made by dissolving ordinary soap in water at the rate of one pound of soap to eight gallons of water. Scale and mealy-bug are more difficult to dispose of. The surest way is to wash them off with a sponge and soapy water; if this is impracticable, kerosene emulsion or one of the proprietary insecticides, used as a spray or dip, will, if persevered in, ultimately dispose of them. Red spider flourishes in a warm, dry atmosphere such as is usually found in living rooms, and if it once obtains a footing it is extremely difficult to control. Washing, as in the case of mealy-bug, is the best remedy; failing this, the under sides of the leaves should be sprayed with water with sufficient force to dislodge the insects.

All house plants are benefited by being placed out-of-doors during the warm summer months. This is especially true of azaleas, which should be placed in a partially shaded position outside as soon as danger of frost is over. All pot plants when grown out-of-doors should have their pots plunged to the rim in earth or ashes, as this helps to prevent the soil from drying out too rapidly, and also effects a saving of labor so far as watering is concerned.

Following is a list of plants that, given reasonable care, will thrive under house conditions:

FOLIAGE PLANTS

Scientific names	*Common names*	*Remarks*
Araucaria excelsa	Norfolk-island-pine	
Asparagus plumosus	Fern Asparagus	
Aspidistra lurida	Common Aspidistra	
Begonia rex	Rex Begonia	
Cocos weddelliana	Weddell Palm	All palms delight in a well drained rich soil and abundant moisture
Cordyline (Dracaena) indivisa	Blue Dracaena	
Cyperus alternifolius	Umbrella-sedge	Pot should be kept partially submerged in water
Dracaena godseffiana	Gold-dust Dracaena	
Ficus elastica	India Rubbertree	
Ficus pumila	Climbing Fig	Trailer
Hedera helix	English Ivy	Trailer—good for growing in shade
Howea (Kentia) belmoreana	Belmore Palm	
Howea (Kentia) forsteriana	Forster Palm	
Nephrolepis exaltata bostoniensis and many varieties	Boston Ferns	
Pandanus utilis	Common Screwpine	
Saxifraga sarmentosa	Strawberry Saxifrage	Trailer
Tradescantia (several species)	Wandering-jew	Trailer

FLOWERING PLANTS

Scientific names	*Common names*	*Remarks*
Azalea indica	Indica Azalea	Likes peaty soil
Begonia argenteo-guttata		Begonias grow best in a compost containing a good proportion of leaf soil
Begonia semperflorens	Perpetual Begonia	
Begonia Thurstoni	Thurston Begonia	
Camellia japonica	Common Camellia	Likes peaty soil
Cyclamen		
Epiphyllum (Phyllocactus) vars.		
Impatiens sultani	Sultan Snapweed	
Pelargonium domesticum	Lady Washington Geranium	
Pelargonium zonale	Horseshoe Geranium	
Primula sinensis	Chinese Primrose	
Zantedeschia (Richardia) aethiopica	Common Calla	Needs rich soil and abundance of water
Zygocactus (Epiphyllum) truncatus	Christmas Cactus	Use rather poor soil
Bulbs in great variety		

Except where otherwise specified, loam, with a small proportion of decayed manure, should be used as potting soil.

The nomenclature followed above is that of "Standardized Plant Names" published by the American Joint Committee on Horticultural nomenclature (1923).

Montague Free.

BROOKLYN BOTANIC GARDEN

LEAFLETS

SERIES XIV BROOKLYN, N. Y., APRIL 21, 1926 NO. 2

"NATURALIZED" BULBS

One of the most delightful ways of displaying the attractions of the spring-flowering bulbs is that of "naturalizing" them in lawns or grassy areas in the garden. If soil and climatic conditions are right, if a suitable selection of bulbs has been made, and if the leaves are not removed from the bulbs before they are properly matured, one may expect such plantings to increase in beauty year by year owing to natural increase in the number of bulbs.

When planting them in lawns those bulbs* should be chosen which bloom and mature their growth early in the season so that the necessary mowing of the lawn may not be unduly deferred. In this class we may include Crocuses, Glory-of-the-Snow (*Chionodoxa luciliae*), Winter-aconite (*Eranthis hyemalis*), and Snowdrops (*Galanthus sp.*)—the two kinds last mentioned succeeding best in partial shade. If the planting is to be done in a hay meadow or in areas where the grass is allowed to grow tall, it is not so important to select such early blossoming kinds, but it is desirable to plant only those varieties whose stature is sufficient to ensure their being visible in the tall grass. It is amongst the Narcissi and the Tulips that we find most varieties that possess these qualifications. In general the lower priced varieties are most likely to succeed in these informal plantings. The fact that they are low priced indicates that they have a hardy constitution and that they increase readily.

Double-flowered forms, and those kinds that suggest formality—Hyacinth, for example—should be avoided in naturalistic plantings. A better effect is gained if the bulbs are planted in groups of varying size and outline, containing from five to a hundred or more bulbs, rather than in solid masses. These groups in general should be longer than wide and the bulbs thickly planted in the center, thinning out towards the edges. The easiest way to avoid formality is to scatter the bulbs over the surface of the ground and plant them where they fall. They may be inserted in holes made with a dibber; or, holes may be made by lifting the sod with a mattock or a spade.

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* The word "bulb" is used in its broadest sense, and includes corms, tubers, and rhizomes.

Then place one to five bulbs in the opening, afterwards replacing the sod. The depth of soil over the bulbs should be equal to two or three times their height. It is a good plan to cover the plantings in the fall with a three-inch layer of strawy manure which should be removed in the spring before the bulb shoots appear above ground.

During the past five years over 140,000 bulbs have been planted in lawns and grassy areas throughout the Brooklyn Botanic Garden, and in addition, many hundreds have been planted in informal groups in the Rock Garden.

The earliest of the spring bulbs may be expected to exhibit their flowers sometime between the first and last weeks of March. The first ones to show their heads above ground are the Snowdrops, followed in order by the Winter-aconite and the yellow Crocuses. A week or ten days later the purple Crocuses make their display, accompanied by the Siberian Squill (*Scilla sibirica*).

The Snowdrops in the Botanic Garden may be seen underneath the Oak trees, immediately south of the collection of Barberries. The Crocuses are planted in the southwest part of the Garden, beginning just north of the Azaleas, and extending along both sides of the walk which runs parallel with Flatbush Avenue. The Winter-aconite, with its dainty buttercup-like flowers, rising from a ruff of green, displays its charms under the Willows by the boulder bridge. It did not come up to expectations this spring because of the severe tramping to which the ground in this section has been subjected.

About a month after the first Crocuses, the Trumpet Daffodils (*Magnicoronati* or large-crowned kinds) may be expected to blossom. There are many thousands of these, of the "Emperor" variety, planted on the knoll southwest of the Laboratory Building. These are followed after an interval of a few days by the variety "Sir Watkin," which belongs in the *Mediocoronati* or medium-crowned group. This variety is to be found on the southeastern slope of Boulder Hill, not far from the Laboratory Building. Northeast of this planting, extending almost to the lake, is another variety, "Lucifer," which belongs in the same group. On the west side of Boulder Hill, somewhat south of the Cedars of Lebanon, is still another variety, "Stella."

On both sides of the brook north of the Terminal Pool is a planting of *Narcissus odorus*, "Orange Queen," which is a type that is seldom seen in gardens. *Narcissus odorus* is the Campernelle Jonquil and is by some regarded as a hybrid between *N. jonquilla* and *N. pseudonarcissus*. *Narcissus jonquilla* is the Jonquil, and belongs in the *Parvicoronati* or small-crowned group. *Narcissus pseudonarcissus* is the Common or Trumpet Daffodil.

About two weeks after the first Trumpet Daffodils show their flowers, the early flowering variety of Poets Narcissus, *Narcissus poeticus ornatus*, is in full bloom. These, to the number of about 15,000, are planted among the collection of young trees west of the White Oak Circle.

The Grape-hyacinths (*Muscari*) come into bloom about the same time as the Trumpet Daffodils. *Muscari botryoides*, variety "Heavenly Blue," is planted just south of the Rock Garden; and about one hundred feet farther south, amongst the Viburnums, is a grouping of *M. elegans*. In the grass immediately north of the Rock Garden is planted the exquisite Dwarf Blue Hyacinth (*Hyacinthus azureus*) which much resembles a Grape-hyacinth, and is commonly sold under the name of *Muscari azureum*.

What is perhaps the most brilliant color display in the Botanic Garden is made by a mixed planting, 20,000 in number, of the glowing scarlet *Tulipa "Gesneriana Spathulata"* and the clear yellow *T. "Gesneriana Lutea."* These may be seen on the slope southwest of the Conservatories around the first week in May. These belong in the "Cottage" Tulip group.

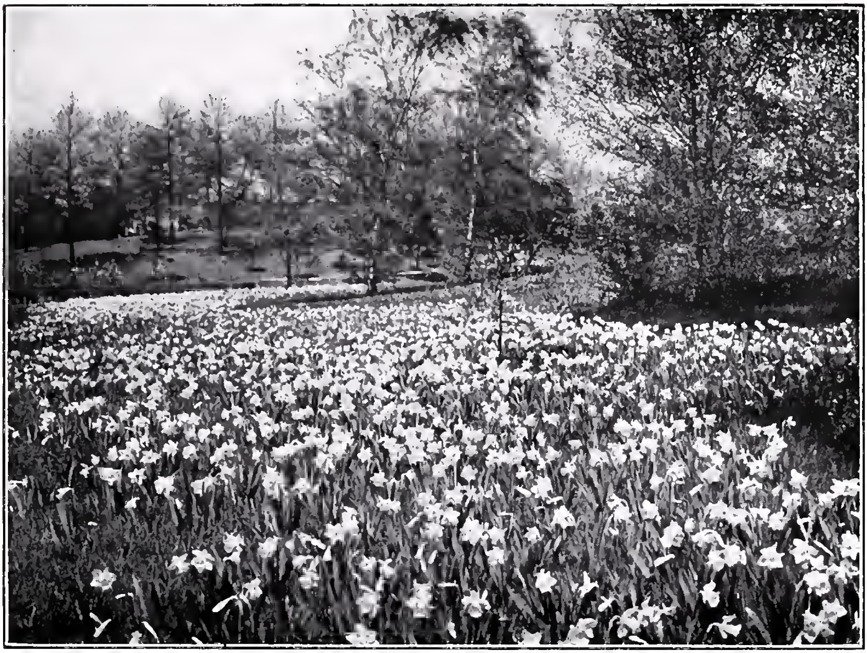

Figure 1. Twelve thousand Trumpet Daffodils of the "Emperor" variety, naturalized in the lawn west of the Laboratory Building, Brooklyn Botanic Garden (3929).

The Checkered Fritillary or Guinea-Hen Flower (*Fritillaria meleagris*) has not taken very kindly to the soil and climatic conditions in the Botanic Garden, and the thousand bulbs of this species planted in 1923 in the grass north of the collection of birches have sadly diminished in numbers. However, there will probably be a few left to display their charms this spring.

In the Rock Garden there is a succession of bloom provided by various bulbous plants, from the latter part of March to late in May. The Spring Meadow-saffron (*Bulbocodium vernum*) and several mountain species of *Crocus* are usually the first to appear, followed by *Iris reticulata,* a bulbous iris with bright purple flowers which hails from Asia Minor; Grape Hyacinths in several varieties; the Glory-of-the-snow (*Chionodoxa luciliae* and others); the Siberian Squill (*Scilla sibirica*); the Twinleaf Squill (*Scilla bifolia*), and many dwarf species of *Tulipa* such as *T. clusiana, T. linifolia, T. dasystemon,* and others.

Of the formal bulbous plantings in the Botanic Garden, the most noteworthy are the collection of *Narcissus* containing about 100 varieties along the west fence of the Experimental Garden, and the tulip collection in which the different groups (Early, Double, Parrot, Darwin, Cottage, Breeder, etc.) are well represented. These are in two beds on either side of the walk immediately south of the White Oak Circle.

MONTAGUE FREE.

NOTICES

The Garden is open free to the public daily, from 8 a. m. until dark; on Sundays and holidays from 10 a. m. until dark. The Laboratory Building, containing the library, herbarium, and offices, is open daily (except Sundays), from 9 a. m. until 5 p. m. (Saturdays, 9-12). The Conservatories are open April 1-October 1, 10 a. m.-4:30 p. m. (Sundays, 2-4:30); October 1-April 1, 10 a. m.-4 p. m. (Sundays, 2-4).

To Reach the Garden take Broadway (B-M.T.) Subway to Prospect Park Station; Interborough Subway to Eastern Parkway-Brooklyn Museum Station; Flatbush Avenue trolley to Empire Boulevard; Franklin Avenue, Lorimer Street, and Tompkins Avenue trolleys to Washington Avenue; St. John's Place trolley to Sterling Place and Washington Avenue; Union Street and Vanderbilt Avenue trolleys to Prospect Park Plaza and Union Street.

Entrances—On Flatbush Avenue (1) near Empire Boulevard (Malbone Street), and (2) near Mt. Prospect Reservoir; on Washington Avenue, (3) south of Eastern Parkway, and (4) near Empire Boulevard; on Eastern Parkway, (5) west of the Museum Building.

The street entrance to the Laboratory Building is at 1000 Washington Avenue, between Eastern Parkway and Empire Boulevard and opposite Montgomery Street.

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BROOKLYN BOTANIC GARDEN

LEAFLETS

SERIES XIV Brooklyn, N. Y., May 19, 1926 Nos. 3 - 6

ENVIRONMENT, VARIATION AND THE LAWS OF HEREDITY*

> "The organic world as a whole is a perpetual flux of changing types."—*Francis Galton.*

Infinite, endless variety is the most striking fact about the world in which we live. As though from a huge magic box, an Aladdin's cave, so to speak, new types of plant and animal life constantly issue forth. You see them in your gardens as vegetable, fruit, or floral novelties; or at the flower shows as new carnations, roses, or orchids. You see them in the plant-breeders' gardens, at the trial grounds of the great seed-houses, in the breeding pens of stock-raisers, or at the fanciers' shops. And last you meet them on the street as friends, especially if you are a citizen of one of those great pioneer countries such as the United States, Argentina, or Australia, where the shackles of tradition are still mere threads, and the "melting pot" accepts almost all "comers." No corner, however minute and obscure, of earth's vast stretches of sea and land, lacks in diversity of animate form or color to those with the seeing eye. And this is as true of the vast deserts and the tiniest bits of pond-mud as it is of the verdure-clad tropical river valleys of Brazil or Central Africa, where life, even to the most superficial observers, appears kaleidoscopic.

So seldom is one of nature's forms duplicated, that even when an approach is made to it, as in the case of identical twins and the so-called "doubles" in man, the greatest wonderment is excited. Our neighbors and acquaintances are alike only in a few so-called fundamental characters. We have no difficulty, as a rule, in distinguishing them, even at a distance, or often without seeing them. Many have a peculiar gait, others have easily distinguishable voices. Some are short, others tall, with all degrees of intermediates between. Their eyes are brown, hazel, gray, blue, or pink, and a score of distinct intermediate shades too slight or too numerous generally to describe by name. Their hair comprises all degrees of diversity in form and color, from that which hangs in golden ringlets to that of the deepest, straightest black. Their temperaments, too, vary as strikingly as their other characteristics, or perhaps even more so. Some are musical, and some, like Darwin, are unable to distinguish between tunes. Some are methodical, others are erratic. Even those characters which we commonly are prone to think are absolutely unvariable, such as the number of fingers or toes, occasionally exhibit variation. In fact there are said to be whole families with more than the normal number of fingers and toes, and webbed feet are by no means uncommon. Authentic cases of people with tails 3 to 5 inches long are known, while in South Africa there is one record well authenticated of a young man with a horny outgrowth about 8 inches long springing from his forehead. Close relationship, as among the members of the same family, does not eliminate this diversity of character. How many times are parents and relatives driven to the most wild speculations to account for differences between brothers, between sisters, or between children and parents. Some characteristics we ascribe to heredity, others to environment, but in many cases neither environment nor heredity seem to explain the appearance of strange characters.

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* This leaflet is a revised reprint of Number 2, Series VI.

In the plant world, as in human beings, exact likenesses as seen by the eye of the specialist are rare. And this is true, even when plants are of the same variety, coming from seed produced by many generations of inbreeding. But what is still more striking is the diversity among plants of varieties propagated by cuttings, budding, grafting, or by offshoots—plants that are only isolated parts of the same plant—as, for example, the Boston fern and its hundred or more well-marked varieties, our fruit trees and berry bushes, and many of our house and bedding plants. Nectarines are found on peach trees, and white-flowered or light-colored forms of chrysanthemums and azaleas blossom out on plants largely covered with darker colored flowers. You have no trouble in distinguishing your own house plants—your own pots of geraniums, aspidistras, crotons, and ferns from those of your neighbor, even though his be of exactly the same kind. Yours show better or perhaps worse care. Your geraniums have had twenty blooms in one month, his only two in the same length of time. Detailed observations have taught us that even the leaves, flowers, and branches of the same plant, as well as the plant individuals themselves, are as unlike each other in many cases as are our friends. Examine the leaves of a mulberry tree, a Persian lilac bush, or those of a fern-leaved beech, and see for yourself the numerous forms they take on even the same branch. Compare a dozen radishes of the same variety pulled at random from your own garden, or a dozen strawberries picked from the same plant, note their differences, and be convinced of the commonness of intra-varietal variation.

The navel oranges of the west all come from parts of one original tree, as do also the Baldwin apples of the east. The original tree which first gave rise to these navels was found near Bahia, Brazil, in the forepart of the last century. Though all the thousands of navel orange trees are parts of this one tree, propagated by budding, every one knows that the fruit of these numerous trees varies in grade and kind—as to form and coloring, sweetness and sourness, thickness of rind, size, and in productiveness per tree. Those grown in Florida (for they were once tried out there) were sweeter than the California product. In some of those from Arizona, the skin is at least of double thickness. What is true of the orange is true of the apple varieties. The Albemarle (Newtown) Pippin from Virginia is a different apple in taste and texture from those of the same variety grown in California. Western apples of almost any variety are deeper and more highly colored than those of the same variety from the eastern states, while the apples of this latter region are on the whole better flavored. In cool, elevated or mountain regions, the shape of the fruit of most varieties changes to a flatter form than those of the same variety grown in plains regions. Even the much despised Ben Davis loses some of its pumpkin-like texture and potato-like taste when grown in the region where it originated.

Cabbage grown in certain parts of the tropics never heads. As is well known, most varieties of lettuce will head only during cool weather. Turnip-rooted radishes grown in hot weather are always pithy, but this is not true of the summer growing kinds such as Strassburg. Beets or radishes grown in too much shade produce luxuriant tops, and woody, slender roots. The flax growers of the northwestern states were threatened with the destruction of their crops by a disease called flax wilt, but fortunately some of the flax plants were immune to the disease and these were isolated and resistant varieties produced. Perhaps the most striking variations are those commonly styled "freaks"—such as pineapples with thirty crowns, two-headed turtles, five- or six-legged lambs, Siamese twins, single apple trees inherently (not grafted) producing both red and yellow or sweet and sour apples, fasciated plants from normal ancestors—the common example of which is the garden cockscomb. In a park in Beecroft, Australia, there is an especially striking example of fasciation in the Norfolk Island Pine—the specimen resembling a giant cockscomb (*Celosia*) over twenty-six feet high. Fasciation (flattened stem) is found probably in all species of plants. Another striking example of it (described in a previous leaflet on *Nicotiana*) is that of a single plant discovered near Alquiza, Cuba, in a field of Havana or Cuban tobacco, a variety normally possessing only eighteen to twenty-four commercial leaves, but the fasciated specimen had over one hundred and fifty. A type of pea with a fasciated stem has been known for over three hundred years. Many types of fasciation are inherited under all ordinary conditions, while some types may only be brought about by disease or insect damages. On the Pacific coast, the spraying of orchards with insect poisons is a general and efficient practice, but recently a scientist has made certain observations which seem to show that the present kinds of spray remedies may not always prove efficient, as constant spraying has served as a selective agent whereby certain insect individuals naturally immune to the spray, have been isolated and enabled to increase more rapidly because of the destruction of their non-immune brethren. Just so have contagious diseases among the Chinese from time to time killed off those which lack natural immunity, until now, as a race, they are practically immune to a large number of the diseases which are fatal to Europeans.

So great a place in the living world is held by this thing called variability that with all their best efforts, our breeders, agriculturists, and seedsmen have hard work to keep it within legitimate and desirable bounds. Varieties of vegetables and flowering plants must be carefully watched on the big seed farms to keep down the "rogues" or worthless variations. Stock breeders must be ever on the alert to keep their breeding animals up to the standard breed type. Grain growers, potato farmers, and florists suffer from the so-called "running out" of once valuable varieties. Varieties of fruit and vegetables valuable in one locality prove worthless in another and *vice versa.* That is why our forefathers here in America had to start all over again instead of using the varieties they brought from their old home. That is why our eastern grapes are of the Concord type instead of the old world solid flesh type, such as are successfully grown in the new world only in California. That is why every section of the world, differentiated by climate or soil, needs its own made-to-order varieties of fruits, vegetables, and flowers—its own local plant-breeders. And in order to furnish material for the making of these varieties, the national Department of Agriculture has explorers and correspondents in all parts of the world on the lookout for new and strange varieties and species of vegetables, flowers, and fruits. Many of these by themselves may prove almost worthless to us, but certain characters they have may be extremely valuable when combined through crossing with the desirable characters of other varieties. For example, the all but worthless Japanese hedge orange, *Poncirus trifoliata,* has sour, undesirable small fruit, but is hardy, even on Long Island. Crossed with the much less hardy orange, desirable varieties of fruit called citranges, hardy much further north than the orange, have been produced.

Varieties of plants and animals are very likely to develop new traits and new characters when exposed to new sets of conditions. Thus the kea parrot of New Zealand changed from a herbivorous to a carnivorous bird some years after the introduction of sheep, and hence became a great pest. Marked changes of color in certain species of birds are said to be brought about by changes in the substances on which they feed. The tall trees of one country may be the dwarfs of another. The Mexican Parthenium or guayule rubber plant failed to produce as much rubber when taken away from its desert environment and cultivated. The obscure and little known insects and wild plants of one part of the world may be the scourges of another, as for example the Chinese San José scale in America, the American cactus in Australia, the Russian thistle in western America.

But on the other hand, after all that has been said concerning variability, it is still a fact that certain living organisms are so strikingly similar as regards certain characters, that we are able to group them roughly into varieties, species, genera, and families. Certain characters appear to be less variable than others, both inherently and when subjected to differences in environment, and these are known as fundamental characters and are often made the basis for the groupings mentioned above. This grouping or classification, however, is in many respects artificial and must always remain more or less so—serving largely as a convenient method of keeping track of them—of pigeon-holing them, so to speak, so that we may talk about them. A striking illustration of the stability of certain characters is that exhibited by plants propagated by bulbs such as tulips and hyacinths. We are told, on the authority of Darwin, that a certain Dutch bulb-grower was repeatedly able to identify 1,200 varieties of hyacinths by observations on the bulbs alone.

There are said to be over 200,000 reliable species of plants, and for the most part there is very little difficulty in identifying them by certain character descriptions. But sometimes these species are not so sharply differentiated as the descriptions in the manuals would lead one to infer, and specimens that one specialist might consider as species *A*, would be classified by an equally eminent authority as species *B*. The story is told of a certain eminent botanist to whom was sent a plant for identification, that he identified it as species *A* the first year, and on receiving specimens from the same plant the second year, he classified it as species *B*, remarking in self-defense when the circumstances were explained to him, that his conception of species *A* had changed in the interim.

Such plants as the little shepherd's purse and the brake-fern occur in the temperate zones of both hemispheres, and are easily identified. But some species undergo radical changes in appearance as environmental conditions change, just as certain varieties of the pink-flowered hydrangea become blue-flowered when grown in soil containing alum, and a certain variety of primrose with red flowers has only white flowers when the temperature in which it grows is raised fifteen degrees.

Variation is so rife among the characters of some plants that even the greatest specialists on classification find great difficulties in so classifying them that one scientist will understand what the other is talking about. For example, the genus *Rubus*, to which our blackberries and raspberries belong, contains, so some authoritics say, 1,500 species, while others classify the same material into 200 groups.

When the attempt is made to call all the individuals springing from seed of the same plant a species, variation again causes trouble. Hybridization is extremely common among all cross-fertilized plants, and the characters of two closely related species which cross are shuffled and form new combinations with each other, so that often a motley array of progeny is produced when seed is sown. Seeds from botanic gardens often excellently illustrate this, but the same result will happen in nature where the species occupy the same general territory. Variation in species, as previously noted, arises also in other ways. Many new types arising in nature may be lost unless extremely favorably situated, and this contributes toward keeping species stable. The same species of wild plants that apparently breed so true in nature, when brought into cultivation under the watchful eye of the gardener, in most cases become extremely variable—perhaps because the gardener is on the watch and gives the new variation a chance. At any rate, wild species under cultivation generally break up into a large number of forms so strikingly distinct from each other, that they would be given specific rank had they been found wild. Take the sweet pea, the purplish-red flowered wild ancestral species of which is native to Sicily. Occasionally white-flowered sports are found wild. The varieties of sweet peas are legion now, and many would be accorded specific rank unhesitatingly were they found wild. The same is true of the petunia, which ancestrally traces its origin back to two wild South American species. The variation that has come about in the chrysanthemum since its first domestication by man is perhaps the most marvelous of all. The supposed wild species are two, one with small white and one with small yellow flowers. The two species are very similar in other respects. While some plants have varied greatly since man has had them under observation; others, perhaps cultivated equally as long and observed just as carefully, have given rise to practically no variations. This is true of the well-known lily-of-the-valley, and also was true of the various species of strawberries until they were crossed. Only after careful isolation of single plants and several generations of purification by inbreeding, does like begin to produce like, and even then the results are sometimes discouraging. By such methods, variability is reduced to a minimum, and a comparatively pure breeding strain or variety is created.

For centuries scientific men have grappled with this problem of variation, attempting to discover some law or order in all the seeming chaos that it produces. When certain characters were common to both parent and offspring they called it heredity, but often other characters appeared—characters that had been unknown to the ancestral line for generations. The breed of chickens called Blue Andalusian presented an extremely perplexing problem, as about one-fourth of the eggs always produced sooty whites, another fourth

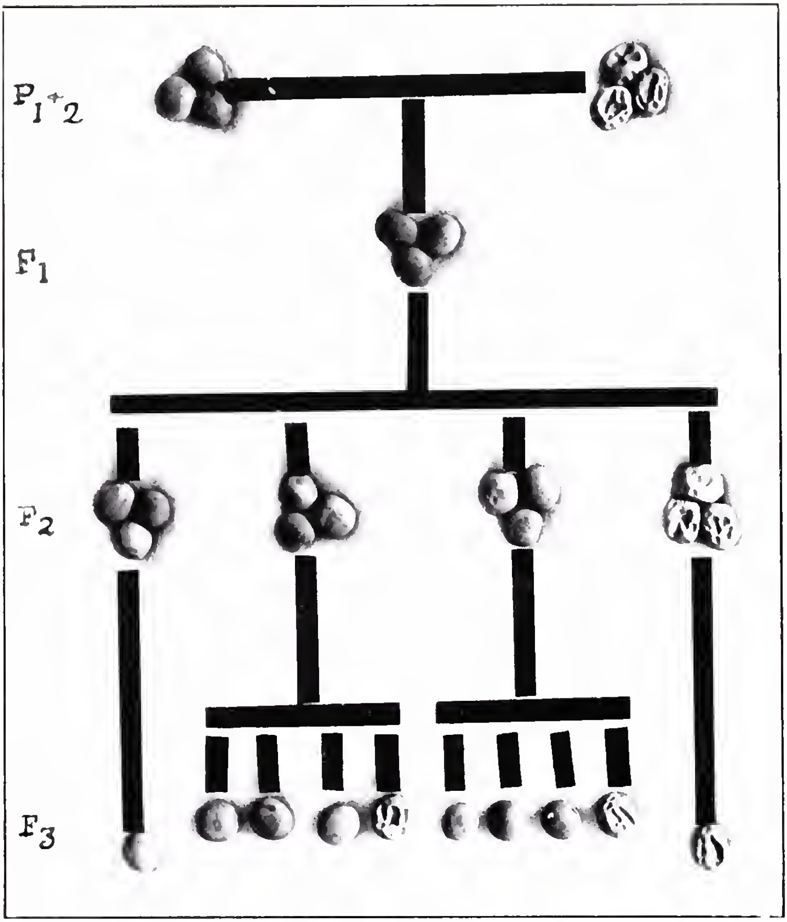


Fig. 1. Diagram showing results of crossing a variety of pea with smooth, round seeds with one breeding true to wrinkled seeds. P designates the two parent types; F_1, F_2 and F_3, the character of the successive hybrid generations.

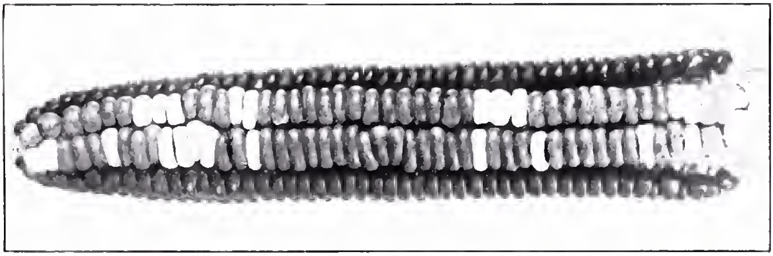


Fig. 2. An ear of corn resulting from crossing a variety having white grains with one having yellow grains, showing the F_2 ratio of three yellow to one white grain. After East and Hayes.

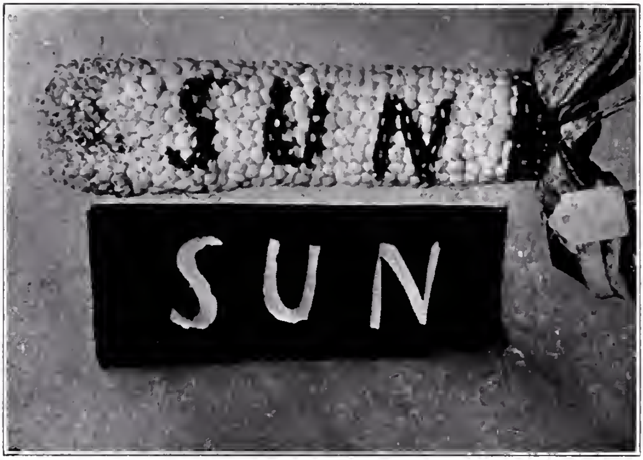


FIG. 3. An illustration of how environment may alter a character. This variety of corn has ears which remain white under normal conditions, but when allowed to mature in the sunlight by removing the husk, they color red. Enclosing an ear in black paper, with the word "sun" cut out, gave the above result, the exposed portions being red, the unexposed grains remaining white. After Emerson.

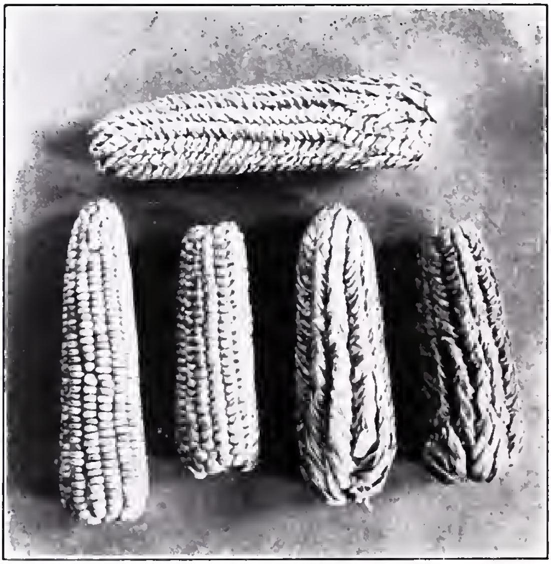
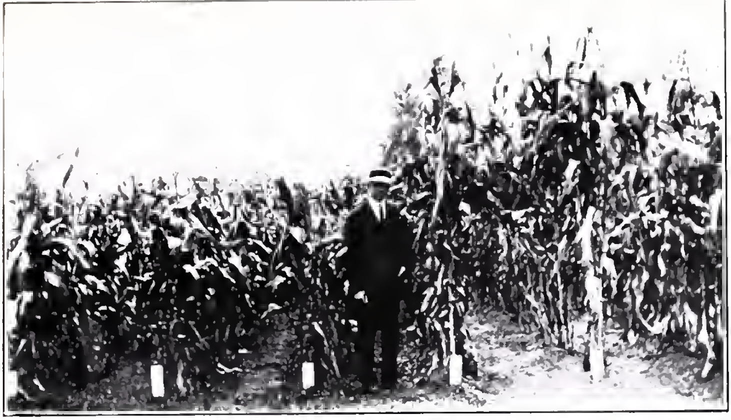
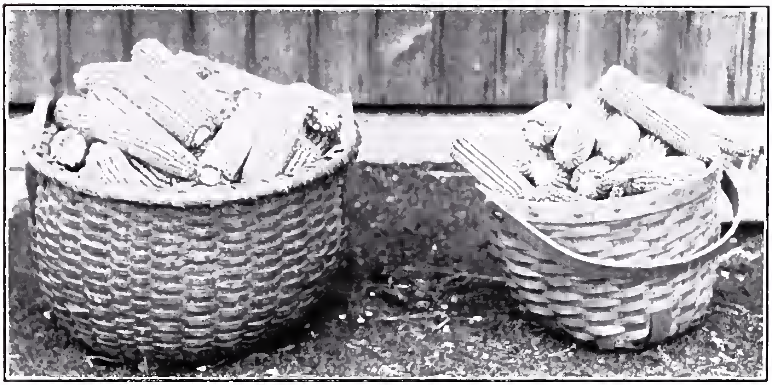


FIG. 4. Mendelian inheritance of the "podded" character in corn. The first hybrid generation above, from a cross of pod and ordinary corn; the four ears beneath representing the character of the F_2 or second hybrid generation. In pod corn, each grain is enclosed by a husk. After East and Hayes.





FIGS. 5 AND 6. Results of crossing two inbred strains of corn. At the left in Fig. 5 are two inbred varieties. The tall corn at the right is the result of crossing them. In Fig. 6, the basket at the right represents the average production of two inbred strains after three generations of inbreeding—61 bushels per acre. The basket at the left shows the first generation results from crossing them—101 bushels per acre. After East and Hayes.

FIG. 7. The "survival of the fittest." Breeding red raspberries to secure a hardy, non winter-killing type for the northern plains region. The staked plants represent the best selections from a large field of crosses and seedlings. After Hansen.

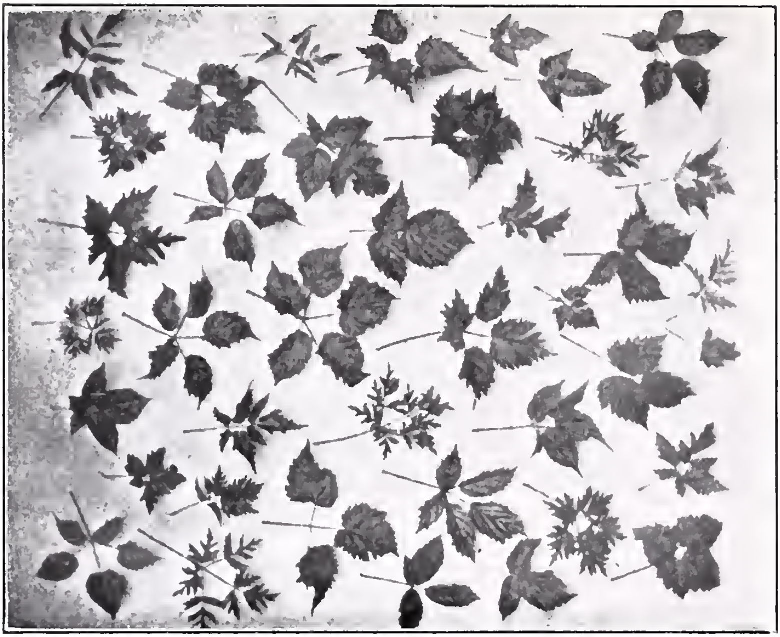


Fig. 8. The various types of leaves from progeny of a single hybrid blackberry plant. After de Vries.

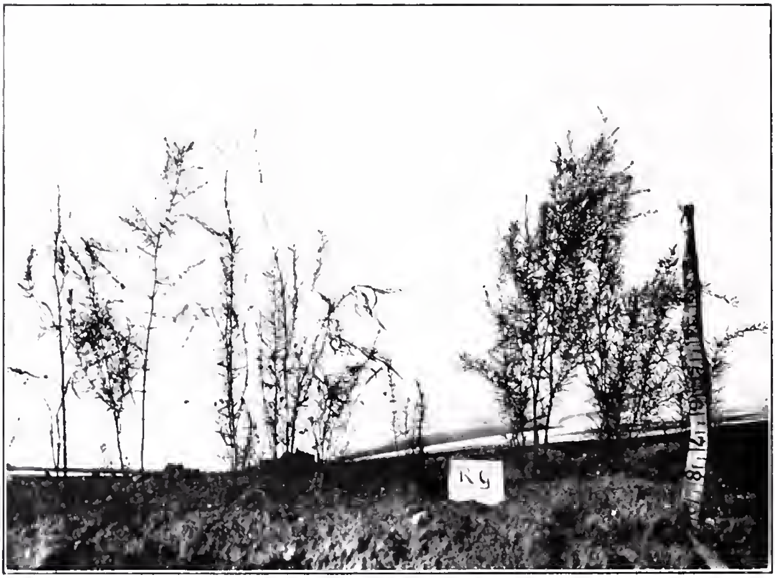


Fig. 9. Breeding disease-resistant asparagus at the U. S. Asparagus Experiment Station at Concord, Mass. On the right are disease-resistant plants, while those on the left are about half destroyed by disease. After Norton.

blacks, and only approximately one half gave typical Andalusians. No amount of selection and inbreeding reduced the number of these off-types. Such cases made men despair of finding any laws of heredity or variation. As soon as one was formulated, exceptions arose which shortly buried the law by their numbers. Superstition was common. Birthmark blemishes faintly resembling strawberries appeared on children, due, so it was said, to mothers having seen or dreamed of strawberries preceding their birth. Hours were spent by mothers before beautiful statues and paintings, that the unborn child might be beautiful. The breeding of fine mares to scrub or to undersirable stallions for a single time was supposed to mar the offspring later of these same mares by fine stallions. Experiments by scientific men were few and far between, and largely resulted in collections of interesting but isolated facts. What was especially needed was some one who could arrange and correlate these facts into a general law. In other words, the rosetta stone had not yet been found. No one had yet discovered the key by which these facts could be interpreted. "Heredity," wrote Balzac, "is a maze in which science loses itself."

Then came the Augustinian monk, Gregor Mendel, a man with a mathematical, analytical mind. With the insight and perseverance characteristic of genius, he outlined some experiments which he believed would throw some light on the inheritance of characters and bring order out of chaos. After much experimenting, he selected peas as the material most favorable for his purpose, made certain that the varieties bred true in certain well defined characters, and proceeded with some crossing experiments between varieties differing from each other in one or more of these tested, true-breeding characters. When a plant with reddish-purple flowers was crossed with one having white flowers, the offspring were not pink, light purple, or intermediate, as one might naturally expect, but all were reddish-purple flowered and indistinguishable from the parent with colored flowers. When the seed of any one of these reddish-purple flowered plants was planted, both purple-red plants and white flowered plants were produced in the ratio of three purple-reds to one white. All the white flowered and approximately one-third of the purple-red flowered plants bred true in the next or third (F_3) hybrid generation. The other purple-red flowered plants (approximately two-thirds of all those in the second generation having purple-red flowers) produced seed which again gave the ratio of three with colored flowers to one with white flowers. From extensive experiments tried since, involving large numbers, there is every reason to believe that two-thirds of those with colored flowers from such a cross after the first generation would always produce plants with colored flowers and plants with white flowers approximating a three-to-one ratio. Other pea characters, amounting to twelve in all (six pairs), were tested by Mendel in this manner, and the results they gave agreed with those of the experiment just cited. These included such characters as the color of the seedcoat, the color and shape of the cotyledon, the height of the plants (tall or dwarf), the color of the unripe pods (green or yellow), and the nature of the stem (fasciated or normal). After satisfying himself as to the manner in which a single pair of characters is inherited, he crossed varieties which bred true to two of these differentiating characters. When tall, yellow-seeded peas were crossed with dwarf, green-seeded peas, the offspring were all uniformly tall and yellow-seeded. When seed of these were sown, four kinds of progeny were produced in approximately the following ratio: nine tall yellow-seeded, three tall green-seeded, three dwarf yellow-seeded, and one dwarf green-seeded. Out of each group a definite proportion bred true to both characters—in the first, approximately one in every nine; and each of the next two groups, one in every three; and in the last group, the dwarf green-seeded plants all bred true.

Space is too short to deal with the character of the remaining offspring in the other three groups except to say that a general law was followed. Although still more elaborate experiments were made, extending over a period of eight years, in which varieties differing in three sets of characters were crossed, nothing of an exceptional nature was discovered. So from these and other results, Mendel formulated the first clear laws of heredity extant—the so-called *laws of segregation and independent assortment*. He found that the different characters in his peas appeared to be inherited as units, and that such a character as tallness could be transferred from a green-seeded variety to one with yellow seeds independently of the other characters such as green seeds with which it had hitherto been associated. The next step naturally then, was to make a general application of the laws—in other words, to consider all animals and plants as being made up of many independent character materials, each of which could be separately inherited. But, as with most pioneer work, scant attention was given to the laws and discoveries which he published in 1866 in the transactions of the local scientific society of Brünn, and during the thirty-four years in which his work remained unnoticed, Mendel died, a disappointed and discouraged old man. It was said he was in the habit of comforting himself by repeating "My time will yet come."

In 1900, three European botanists—Correns, deVries and Tschermak—experimenting along similar lines, each independently rediscovered the laws, and Mendel's long forgotten and neglected account was resurrected and once more brought to public notice. This time a hearing was gladly granted, a new science grew up, and general interest in plant and animal breeding spread with cyclonic rapidity. The study of heredity became a fad which reached its height in the science of eugenics. Through Mendel's work, and the encouragement derived from his discoveries, the nature of variation and heredity and their relation to environment are beginning to be understood. Variations can now be classified from the standpoint of cause, instead of only by form or by appearance. When three varieties of beans, each breeding true to white seed, are crossed with a single variety of bean breeding true to red seed-coats, and in each cross a different colored progeny is obtained (black, dark blue with white specks, brown-gray), we are not thrown back into the old-time chaos. Thanks to Mendel's methods and conception, we have a clue by which we are able to see law and order in this seemingly contradictory result. And what is also very important, we are able to repeat this performance again and again with the same results.

Since 1900 many important modifications of Mendel's original conceptions have come about, as might be expected when scores of experimenters are engrossed in the experimental study of hundreds of different plant and animal forms. Important among these modifications is our conception of what constitutes a character. The vague meaning attached to this term by the older biologists is gradually being replaced by the usage of the chemists and physicists. In this sense, a character must always be looked upon as the combined result of heredity and environment. The heredity units themselves are not characters in any sense, but, in conjunction with environment, express themselves as characters. The units themselves are to be regarded as the primary elements of the "living" world, just as oxygen and sulphur represent elements of the so-called inorganic world. Another modification of Mendel's conception is that of linkage. For we find that certain characters are either partially or always inherited along with other characters—not always separately as Mendel supposed. Many of these characters in certain animals are sex-linked. In the little banana fly, over four hundred of these differential heredity units have been studied and instead of finding that each is inherited independently of all the others, the discovery has been made that they are inherited as though more or less loosely linked together in four groups. In plants, similar discoveries have been made, though not on as large a scale. In peas themselves, colored flowers are found to be partially linked or coupled with the materials responsible for late flowering, while the white flowers are partially associated with the materials responsible for early flowering time. One pea variety with no tendrils and having wrinkled seed, crossed with a smooth-seeded, tendrilled variety, gives smooth-seeded, tendrilled offspring in the first generation, while in the second, where four types of plants are expected in the proportion of 9ST: 3WT; 3 S non-T: 1 W non-T, approximately only two appear, the two central groups being represented by very few individuals. The two outside groups of course are the same combinations as found in the original parents of the cross, and though the two characters naturally would not be expected to be associated in any way, experimental work has shown us that they are almost completely coupled. There are numerous other modifications of Mendel's ideas, but all of these, though important, are to be regarded as superstructures built by the methods and on the foundation stones laid down by Mendel.

Through the light thrown upon the nature and inheritance of characters by Mendelism, experimenters soon came to a radically different conception regarding the rôle selection played in the creation of new varieties. Wheat, beans, and other plants, once freed from impurities by constant inbreeding, bred practically true, provided they were always subjected to the same environmental conditions. Certain varieties of wheat thus treated by the Vilmorin family of France have remained stable for forty years. Some varieties of peas are said to have bred true for a still longer period. Sugar percent in sugar beets has not been appreciably increased over that obtained during the first years when the selection for a high percentage of sugar began, although more stable varieties have been obtained. On the basis of this kind of evidence, together with that obtained from more recent experimental studies, selection is found not to be the creative agent Darwin and most of the nineteenth century breeders and scientists supposed. Selection, so many experimenters believe, cannot alter the nature of the hereditary units, nor can it cause them to come into existence. Chance, or fortuitous variation, brought about no one knows how, seems to be the only method by which new units arise. To obtain a blue rose from a red-flowered variety, one must wait, so most scientific breeders believe, until a blue-flowered variation occurs—for selection is of no avail except as a method of isolating desired variations that are already in existence. When such variations arise in naturally inbred plants, such as peas, they generally breed true at once; but in cross-fertilized species, such as corn, purification by selection must be practiced to secure a true breeding strain.

Inasmuch as most of the higher plants and animals result from a union of two microscopic cells, and as each of these cells may carry the hereditary units which together with environment are responsible for the characters of these organisms, it follows that every sexually produced animal or plant that breeds true for several successive generations must have at least two of these units, identical in every respect, for *each of the characters* in which it breeds true. The only exceptions are those cases where a number of characters result from one kind of unit, in which case two of these units, exactly alike, may be responsible for several characters, as, for example, in the characters pink flower color, red leaf-axil color, and reddish-gray seed-coat color in peas.

Granting for the time being that the Mendelian method of analysis is applicable to practically all the characters of the world of living organisms—that plants and animals are made up of independent heritable units, which, in combination with environment and with each other, express themselves as characters; and granting further that these units are, for the most part, unvariable and not modifiable by selection, how can we arrange and account for all the variation we see about us?

If the conceptions of Mendel and his followers hold as regards the composition of organisms, variations may only occur:—

> 1. When the complex of hereditary units constituting the organism remains the same, and the external environment (*e. g.*, soil, climate, food) is changed.
>
> 2. When one or more of these units is added to or subtracted from the organism (through crossing), the external environment remaining unchanged.
>
> 3. When both the complex of hereditary units and the environment are altered.
>
> 4. When the environment remains the same, but the complex of hereditary units (the organism) is altered by the "addition" of a new hereditary unit, or the "subtraction" of an old one (the most common type of mutation) or by other so-called mutative processes.

All four of these statements find illustration in almost every plant breeder's experimental garden. At the Brooklyn Botanic Garden, the plant material for the study of heredity is largely made up of peas, castor beans, and corn, in which many units have been isolated. Studies are also being made on variation in the Boston fern and its varieties and in disease resistance in cereals. In Boston, at the Bussey Institution of Harvard University, the material is principally tobacco and corn; and among animals, mice, guinea pigs, rats, and rabbits are undergoing investigation. At Cornell University, beans, corn, morning-glories, and cereals are being studied; while at Columbia University, students are analyzing the hereditary composition of the little banana or pomace fly, of which there are now over four hundred varieties. At Cold Spring Harbor, L. I., numerous studies on various plants, animals, and man are under way, while at the University of Wisconsin, soy beans, pigeons, dogs, etc., are being investigated.

In peas, over one hundred character units have been isolated, some of which are of commercial importance, such as those for tallness and dwarfness, blunt pod, parchmented and non-parchmented pods. In tomatoes, color inheritance has been fully worked out at the New Jersey Experiment Station. An authoritative summary of the studies on color inheritance in animals—pigs, cats, dogs, cattle, horses, guinea pigs, rats, etc.—has appeared in *The Journal of Heredity*.

Heredity units of commercial importance have been isolated for castor beans as well as for many other plants. In corn, many units or factors are known, while in the banana fly over four hundred have been determined. In some plants, crosses between certain varieties (not all) have given increased productivity in the first hybrid generation, and in the case of corn, walnuts, and tomatoes, the use of first generation (F_1) crossed seed is commercially important in increasing the crop (See Figs. 5 and 6).

Among books on plant breeding and genetics, A. D. Darbishire's "Breeding and the Mendelian Discovery" is very readable to a layman, and authoritative. Castle's "Genetics and Eugenics" will appeal to the more practically inclined. Among other readable books on this subject are Jones' "Genetics," "Principles of Genetics," by Sinnott and Dunn; "Evolution, Genetics, and Eugenics," by Newman. More specialized treatment is to be found in books by Professor Morgan and his co-workers.

In a former LEAFLET (Series III, Nos. 10 and 11), directions are given for carrying out plant-breeding experiments in one's own garden—a field capable of affording much pleasure and some profit.

ORLAND E. WHITE.

NOTICES

The Garden is open free to the public daily, from 8 a. m. until dark; on Sundays and holidays from 10 a. m. until dark. The Laboratory Building, containing the library, herbarium, and offices, is open daily (except Sundays), from 9 a. m. until 5 p. m. (Saturdays, 9-12). The Conservatories are open April 1-October 1, 10 a. m.-4:30 p. m. (Sundays, 2-4:30); October 1-April 1, 10 a. m.-4 p. m. (Sundays, 2-4).

To Reach the Garden take Broadway (B-M.T.) Subway to Prospect Park Station; Interborough Subway to Eastern Parkway-Brooklyn Museum Station; Flatbush Avenue trolley to Empire Boulevard; Franklin Avenue, Lorimer Street, or Tompkins Avenue trolleys to Washington Avenue; St. John's Place trolley to Sterling Place and Washington Avenue; Union Street and Vanderbilt Avenue trolleys to Prospect Park Plaza and Union Street.

Entrances—On Flatbush Avenue (1) near Empire Boulevard (Malbone Street), and (2) near Mt. Prospect Reservoir; on Washington Avenue, (3) south of Eastern Parkway, and (4) near Empire Boulevard; on Eastern Parkway, (5) west of the Museum Building.

The street entrance to the Laboratory Building is at 1000 Washington Avenue, between Eastern Parkway and Empire Boulevard and opposite Montgomery Street.

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BROOKLYN BOTANIC GARDEN

LEAFLETS

SERIES XIV BROOKLYN, N. Y., OCTOBER 13, 1926 NOS. 7 - 8

THE WAYS OF PLANTS

To most people, plant activities, as compared with those of animals, are too obscure to arouse much interest. People visit botanic gardens in quest of information, or to surround themselves with a more pleasing world—a world in which they can more easily assume the chief part in the drama. They go to parks as playgrounds, to eat and to be merry. But when they journey to a zoo or watch a wild animal, the bulk of their thought is centered on the animal—on the observed, not the observer. Unconsciously they humanize the animal, and this is simpler than humanizing plants, since there is more in common between animals and human beings than between plants and human beings. Walking along an unfrequented tree-arched path or trail, the pleasure comes from being alone. In the zoo, it springs from association with the animals.

The fact that plant activities are more concealed or less perceptible undoubtedly decreases the pleasure of observing them. Feeding a squirrel or a goldfish is much more sport than feeding a poppy or a daisy. Yet both animals and plants take in nourishment. Plants, either alone or in great masses, appear to most people almost as unalive as stones or sticks. Plants lack that power of quick transition in outward expression that characterizes people and animals. They are dumb, and their motions in most cases seem too gradual to be regarded as action at all. Imagine the surprise of your feminine friend with the pussy-willow wand in her hand if you should say "Look out, it's alive!" Yet it really is, although its movements differ radically from those of a mouse or a snake. But to those people who know them in that intimate fashion that mothers do their children, the relation of plants to all things outside themselves as well as to one another is full of surprise and panoramic change. They are active—intensely so!

At a motion picture show, I once heard a thousand people utter their "ahs!" and "ohs!" in various keys, when a picture showing a bud open into a flower was thrown on the screen. But the tropical water-lily pool at the Brooklyn Botanic Garden gives anyone a chance with free admission to see real buds change into real blooms instead of just their moving, pictured images. Dusk falls, an outer petal slowly moves, the rate of speed increasing, until flip!—it lies in position. Then another, and another repeat the process. The whole flower trembles. The petals crowd and push each other subway fashion. Perceptibly all slowly assume their proper position and the lily flower lies fully expanded, face to the sky, waiting for the silent night fliers—its matrimonial agents.

In the Ecological Section of the Garden, several exhibits illustrate the opening and closing of flowers and the movements of leaves. Four o'clocks open their flowers late in the afternoon, but on a varying schedule. The white-flowered plants flower first, followed by the reds and other colors. In the early morning hours, they close —forever—for the full-bloom life of each flower is less than a day. When it is cloudy, their opening period is longer. The same is true as fall approaches, when the days are colder. For even in the bright sunshine, they often remain expanded at least till noon. "What causes this," you ask? "Primarily, lowering of the temperature," the scientist replies, "although this is not the only factor." Flowers of morning glory, moon-vine, California poppy, Jasmine tobacco (*Nicotiana affinis*), and portulaca follow the same fashion largely for the same reasons. But their hours of closing and opening differ. Their hereditary make-up is not the same. Thus, as with cats and cattle under domestication, their reactions to the same environment are unlike.

With the water-lilies, the Nymphaeas, some are night-bloomers, while others are day-openers. Some species close, others open, as the day grows warmer. The cactus family likewise has its lovers of night-life and sun-life. By day, the Christmas cactus blooms; by night, the night-blooming Cereus. The ordinary commercial tobacco blooms both day and night, but its flower-bed cousin, the Jasmine tobacco, parades its flowers in a less expansive fashion. Crocuses and tulips open on a rising temperature, and close when it begins to fall. With the mercury ascending, growth on the inside of the floral cup is faster than on the outside. As the day cools, the reverse takes place.

I must mention the weeping trees—not the willows, birches, beeches and mulberries that have that adjective attached to their name, for they only look like weepers. No moisture falls. But there are trees in the tropics that exude water so rapidly that it recalls the first drops of a heavy shower. These are often called rain-trees and belong to the pea family. In Calcutta, there is a "weeping" mango tree—a full-grown adult which begins "weeping" at about the same time every day—at 1 p. m.—to the consternation of the awe-struck natives. First a big drop falls once every two seconds, then less and less frequently, until finally it ceases altogether at 5 p. m. From such occurrences, myths and miracles arise. Yet the explanation is comparatively simple. The drops all come from a healthy cavity, high up among the branches, which slowly fills with exuded sap. Until 1 p. m. the cavity is shaded by the leaves. At this time the sun strikes it, causing a rise in temperature and greater pumping on the part of the neighboring pulsating cells. Hence the overflow—the so-called punctual weeping. As the sun moves round, the temperature goes down and cell activity gradually decreases.

But the "weeping" mango is only one of India's bizarre creations. Centuries ago, most occidentals, wise or otherwise, looked upon her and the neighboring regions as the home of all that was queer, exotic, exceptional. Vestiges of this former ignorance remain today in the names of many plants and peoples—cannas are *Canna indica*, maize is known as Indian corn, and our American aborigines are Indians. Columbus died deluded in the belief that he had discovered India. Though we have learned that India does not possess a monopoly on the strange, it is still a region of great surprises—in plants, peoples and pasts. All this digression by way of introducing the "praying palm" of Faridpur that was, for it died years ago from poisoning.

In the evening, when the temple bells were ringing for prayer and meditation, this strange date palm bowed its foliaged head as if it, too, felt the atmosphere of reverence. By morning, again its leafy dome was erect. Every day this curious activity took place, as though it were a conscious gesture. It appeared to many, miraculous. From far and near the pilgrims came, bringing offerings. Through its agency, marvellous cures were believed to be effected.

But Sir Jagadis Chunder Bose, the knighted savant of Calcutta, investigated with the unemotional eye of the trained judge and thus presents the facts. To him it was simply a full-grown rigid tree, over 16 feet in height, that at some time a storm had keeled over to an angle of 60 degrees. Its daily up-and-down stem movement traveled through a 40-inch arc. In the morning its leaves faced upward; its trunk near the crown of foliage was concave to the sky, In the afternoon this curvature was gone or slightly reversed, and the leaves hung downward. Thus the leaves facing skyward at dawn, swung about in the afternoon through a vertical distance of about 16 feet. "To the popular imagination," Bose says, "the tree appears like a living giant, more than twice the height of a human being, which leans forward in the evening from its towering height and bends its neck till the crown of leaves presses against the ground in an apparent attitude of devotion." The cause of this movement, Bose maintains, is not primarily variation in light intensity, as at first would seem to be the case, but variation in temperature. With the rising warmth up to 3:15 p. m., the tree fell. With the descending mercury between this point and dawn (about 7 a. m.) the tree rose to its most erect position.

Experiments with other plants—vines, trees, herbs,—show similar activities in relation to temperature change, but their erect position and surroundings are such that their movements fail to look so striking. At least to those who see with untrained eyes and pass at laymen's speed.

Growing in the Garden and somewhat rivaling the palm of Faridpur in attracting public interest, is the sensitive plant, *Mimosa pudica*. Though dumb, like all plants, it does express itself when touched, be it ever so slightly. This attracts a crowd. Motion begins at the point of contact. If only a leaflet has been fingered, this one and a few nearby will close. Run your hand over a whole plant with its score or more of leaflets, all will close pointing upwards, and the leaf stalk and stalklets will be depressed. Brush the entire plant or a patch of them, and where but a minute previously, all was filmy foliaged green, the bare ground now shows between a few reddish-green twigs and leaf stalks, each but slightly clothed in foliage. In parts of the tropics, where this plant grows as a weed, walking through a patch of them gives one a strange feeling, even if one is previously aware of what will happen. On the dry borders of some Bolivian stream beds, a related species grows into man-high bushes. Shake them, and their limbs stand stark and bare as if a locust swarm had visited them.

Why is the sensitive plant so sensitive? Because, in a measure, perhaps, it is less sensitive than most plants. At least this is the impression the master student of sensitive plant activities left on me when he lectured in New York a few years ago.

But Bose explains himself by stating that excitatory movement in most plants cannot be realized on account of the rigidity of plant structure, thickness of cell-walls, and the absence of facilities for escape of water from the excited cells. In most plants the tissues are equally sensitive to stimuli in all directions. Hence when touched or otherwise incited, the leaves or stems remain apparently static. In the sensitive mimosa, this is not the case. The pulvinus or thickened base of the leaf or leaflet stalk is about 80 times more sensitive on the lower than on the upper surface; on being touched or otherwise excited, the internal pressure of the cells of the lower portion becomes lessened, these tissues contract, growth is retarded, and the leaf falls. In a few minutes, under favorable conditions, internal cell pressure again increases, the tissues expand, growth advances, and the leaf resumes its former position.

But the thousands of electrically recorded graphs of sensitive plant activities made by Bose tell a much more detailed story than this. Through these the plant registered its behavior to various chemicals, to heat and cold, to over-excitation (that is overwork or being touched too often), to daylight and dark, to blue light and red light, to moisture, drought, the passing of clouds and old age. It is a way of giving the dumb plant a voice. With such a voice or voices, for the devices used were numerous, the plant told many things about itself that could not possibly be learned in any other way. It exhibited fatigue, which is a scientific way of saying "it got tired." It found hydrogen peroxide stimulating. From these and other experiments, Bose found stimulation was transmitted through the leaf stalk in summer at a speed of 30 mm. a second. In winter the rate was slower. This means that the effect of touching a sensitive plant travels through its tissues at a higher velocity in summer than in winter.

The sensitive plant belongs to the great pea family. Among its thousands of relatives, many show various degrees and kinds of sensitiveness. The so-called telegraph plant—*Desmodium gyrans*—on hot days in our greenhouse does an automatic up-and-down wigwagging performance with its leaflets that Bose compares to the beating of the heart. Kentucky coffee trees, Coronilla, and the sensitive plant itself all close their leaves as darkness falls. The peanut flowers and buries its fruits in the ground and does it just as consciously as many people eat their dinners.

Dionaea or the Venus fly-trap catches insects—small ones. Of course, it cannot chase them, but let one light upon the upper surface of its expanded, fringed, hinged leaves and see what happens. It shuts like an automatically closing pocket-book. In the Carolina swamps, the home of this remarkable plant, many a dainty insect has lost its life in this way, and furnished its captor a meal. For the plant digests them as truly as any sparrow would. Thus it reverses the usual order of things in the living world.

Sap-running, or "the ascent of sap," as the botanists more formally put it, is a universal plant activity. Plants all have sap, just as all the higher animals have blood. And what blood is to us, sap is to plants, although I do not mean to imply that they are at all similar. You can kill with pistols or with swords. They are not alike, but both are weapons. Thus it is with blood and sap. Their value to their respective types of life is much the same. They both do an export, import, and distribution business.

One of the well-known saps is maple sap. It comes from *Acer saccharum,* the hard-maple tree. When spring arrives, and cool and crisp nights are sandwiched between sunny days, the inhabitants of Vermont and other neighboring latitudes invade the sugar bush, the groves of gray-barked maple trees. Then ensues a period of feverish human activity—tapping, carrying, boiling, and sugaring-off. The cause you've guessed. The maple trees' food factories are again being set in motion. Water full of last year's manufactured product, largely in the form of sugar from the warehouse of the roots and main trunk, is being sent to the outermost extremities of the tree. There it will start the processes in the buds that turn them into leaves that will produce more food—more maple sugar—for next winter's store. As the sap goes up, these busy Vermonters tap the trunks and tiny tubes and take part of the supply for their own purposes, just as bee people take honey from the bees. In both cases, the sweets are stolen. Not in any sense are they made for man.

How fast does the sap run? That depends on the kind of tree it is, for even among maples, some are sappier than others. The running rate differs from tree to tree. Exact figures I do not possess, but as high as 30 quarts have been taken from one tree in the short sap season. This indicates considerable motion.

Wouldn't it be thrilling if one's ears were attuned to hear this activity? Think of walking in the springtime forests, listening to the sap ascent. But intimate knowledge of plant life makes it easy to imagine, so maybe after all, we do not lose so much. For ears so tuned, all sounds brought newly within our range, would by no means be pleasurable.

Black birch sap is sometimes used for sugar making, and there is on record a tree that produced almost 1900 gallons in 30 days. Think of it, 63 gallons of sweet sap a day!

In the wet "romantic" forests and messy, tangled jungles of South America, rope-like vines (lianas) hang from the tall trees. Through their cells and tubes the sap races at terrific pressure and speed. So rapid is this rate that a pint per minute passes a given point. Some of these the natives of the regions utilize for drinking purposes. Our common willows, by comparison, are sluggish creatures. Their sap rises only three feet an hour. In the sunflower, it progresses eight times as fast, while the plant from which our "smokes" come is almost as slow as the willow, its record being four feet an hour.

Of course the velocity at which sap ascends depends on many things outside the plant, as well as on the make-up of the plant itself. Temperature, humidity, and amount of moisture in the soil are some of the most important. On warm, windy summer days, big trees transpire enormously and thus lose lots of moisture. Then the sap flow is faster, other conditions being favorable. Bose says that sap in the Impatiens plant climbs upward 23.5 inches an hour when the temperature is 86°F., and there are other plants under certain conditions in which the sap moves over a foot a minute.

Many have speculated, theorized, and conducted experiments on what makes sap go up and down. Is it pressure from the water the roots take up, the pull caused by the loss from transpiration or the small diameter of the sap-conducting tubes? All three seem to operate. The distinguished knight mentioned above, maintains, on the basis of his experimental work, that another factor is very important —the plant pulse, or the rhythmic beat of the cells. This pulse, like our heart, plays a large part in pumping the sap upward.

Still another picture of the activity of plants is gained from their propagative proclivities. For example, the tiny plants that most people call "germs" or "microbes" and that scientists call bacteria and yeasts multiply at such an enormous rate that jocular remarks concerning reproduction in rabbits and guinea-pigs completely lose their point. Within 24 hours many kinds of "germs" have millions of offspring. Whole cities of them grow up when favorable conditions arise in a nose or a throat. We call these germ communities and their activities—"colds."

Or again, a small yeast village floating in the air lands in a bowl of cooked prunes or peaches recently set away on the pantry shelf and mother says "it's fermenting." But in ordinary English, the yeast village has found a favorable site and is booming into a city, and the fermentation is one of the activities of the boom. If the magnifying power of our eyes was only a few hundred times greater, we would see enormous industry in this yeast city. As things are, most of us must content ourselves simply with feeling and tasting the results of it.

Germs can travel, too, their estimated speed being about four inches an hour. "Pretty slow," you say, yet a man going at the same rate, in proportion to his size, according to Prof. A. I. Kendall, would be making over a mile a minute.

Only users of microscopes are privileged to witness the intimate details of germ life. But in the terminal pond of the brook in the Brooklyn Botanic Garden, each year is placed a handful of the tropical water fern, *Azolla filiculoides,* a little floating plant about a quarter of an inch in diameter, which reminds me of point lace doilies. I suppose because it is so small, fragile-looking, and beautiful, especially in the fall, when, turning from green to red, it dots the surface of the circular pond of blue water with little patches of red lace work. But that handful multiplies in the most amazing fashion. In July a mere handful—by October the progeny would fill several bushel baskets. If rabbits increased at that rate, a pair in a park would soon mean desert desolation.

Through plant activities, we live and most truly have our being, but through them, we also just as truly often lose it. Street crossings undoubtedly are dangerous, and train wrecks take their toll of human life. A few of us kill each other. Our gravest dangers and our greatest fights, however, are with plants. Our cities are placarded with warnings against them, though few of us think of "no spitting" and similar placards as such. We have special forces of men (the public health department) trained to help resist them. At Christmas time, we buy special stamps to raise money to fight certain kinds of plants. Yet still they often win.

For the primary cause of tuberculosis or consumption consists of colonies of microscopic plants, each individual from 1/12 to 1/6 thousandth of an inch in length. These nefarious "germ" hordes locate in the lungs, multiply, and prosper. In the success of their activities lies our extinction. In 1900, in the United States alone, over 111,000 of us died from their attacks.

Then there is the more cheerful side. Through plants we live, although some of us are great meat eaters. But meat-eating, as the experts tell us, is just a more luxurious way of consuming food made by plants. Hogs eat plants and we eat pork. By eating plants directly, we increase our food supply.

For centuries chemists have been very industrious and very curious. Through these characteristics so intensified in a small group of our kind, we have unearthed great information stores concerning all sorts of matter. But in spite of our decades of research, we human beings still live on plants, or on animals that eat plants. We can not make our own food. We can not take raw earth and air and sunlight and make a breakfast food or a grape fruit, or anything remotely resembling them. We have not found the recipes, although we do know the ingredients and we have some ideas on the subject of how to mix and manipulate them. But these are about as crude as a Hottentot's idea of the manufacture of electric motors.

With the aid of sunlight, leaf green (*chlorophyll*) and other things, plants can take soil compounds or raw earth and atmospheric elements and make real food—starches, sugars and proteins. No ordinary animal can do this. "Man," says Slosson, "takes a 1000 horse-power engine and an electric furnace at a temperature of several thousand degrees to get carbon into combination with hydrogen, yet the little green leaf in the sunshine does it quietly and without getting hot, by the action of enzymes." But remember even this stupendous effort of man's has not yet produced food in the garden sense.

Banish the plants, you banish the animals. Our activities are dependent on theirs. Plants can live alone. We can not. So in the far creation-time when life was born, plants must have come first, and then the animals that ate them.

The sex affairs of the green world have been treated in former Leaflets (Series III, Nos. 10-11, 1915; Ser. IX, Nos. 3-4, 1921), as have also their ancient history, ancestry (Ser. VIII, Nos. 3-5, 1920), and origin (Ser. III, No. 6, 1915; Ser. IV, No. 11, 1916). Why they are what they are and the laws that govern the inheritance of their characteristics are discussed in Ser. XIV, Nos. 3-6, 1926. So there now remain their problems of immigration and the distribution of their young. On these, at present, I can only very lightly touch, mentioning a few of those most striking.

So varied has been the adaptability of plants that from very ancient times, the tides, the ocean currents, the flowing rivers, the brooks, the winds, the birds and beasts, as well as man, have all had a part in transporting their seeds. Cockleburs and stick-tights cling to man and beast and travel where they travel, until dumped upon the wastes or strand by the garbage man or left in some one's dooryard. On many tropic seashores the waves leave the club-shaped mangrove fruit. Through water and man the coconut has settled on the thousand islands and coral reefs of the South Pacific. Russian thistles, the rose of Jericho, and tumble weeds have rolled before the hurricane and blizzard, and planted plains and prairies. Wild beans twist their dried pods and scatter their seeds as the old time sower sowed his grain. Little tufted parachutes have colonized the dandelion upon a million lawns and more. The jewel-weed, balsam, and castor-oil bean have exploded their fruits and planted their seeds as though they had been dynamited. The squirting cucumber, *Ecballium,* shoots its seeds in an unforgetable manner from a water-gun-like fruit, often throwing them 10 or 15 feet. Through these and other ways, the earth was and is sown with plants. Through their multifarious and ingenious activities new territory was and is conquered. They flourished. Then came the parasites, the animals that lived upon them. These in turn were followed by the meat eaters, and by those that lived upon and loved both sap and blood life.

Against the evening sunset stands a lone and rugged pine. One who contemplates this picture feels something of the activities of a plant's life—the living forces that have brought it forth and set it there—the years and years, perhaps even centuries of struggle with wind, and water and other nature elements. The gnarled form is as expressive of an active existence as the lined and withered faces of those among ourselves whose labors have been great.

ORLAND E. WHITE.

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FORMS AND FUNCTIONS OF LEAVES

This LEAFLET is prepared primarily for the assistance of teachers and students of botany and biology who visit the Brooklyn Botanic Garden. It contains brief accounts of most of the various forms and functions of leaves and leaf-like structures in seed plants, using as illustrations the living plants in the conservatories and outdoor plantations of the Garden.

Morphology and Physiology.

The study of the form and structure of plants and plant organs is called *morphology* (Greek *morphe*—form) : that of the functions—i.e. what the organs do—how they "work," is called *physiology* (Greek *physis*—nature). But it is difficult to entirely separate the two in our own thought. As Herbert Spencer says, "Everywhere structures in a great measure determine functions; and everywhere functions are incessantly modifying structures. In nature, the two are inseparable co-operators, and science can give no true interpretation of nature, without keeping their co-operation constantly in view." One's first impulse, after seeing an organ of a plant or an animal and observing carefully its form and position, is to determine what its function is, i. e. "what it is for."

Not all organs or structures necessarily "good for something."

But it is erroneous to assume, as is so often done, that all organs or structures in plants or animals necessarily perform some helpful function. In many cases, like the human appendix, or the last four vertebrae (*coccyx*) forming an extension at the base of the human spinal column, they are simply remnants of organs which in past ages were functional, but now, after countless generations, are only atrophied reminiscences of their former condition. Other structures, also, evidently arise from time to time in the process of evolution, through variation, bringing no harm to the organism, and they may even increase in size in successive generations. These useless structures, in many cases at least, may be linked up, in the inheritance complex, with the parallel development of some structure that is proving advantageous in the struggle for existence.

What constitutes a "leaf?"

Although everyone knows what a green foliage leaf is, there are many structures in plants very unlike an ordinary leaf in appearance, which, however, are really of leaf-like nature, or, as the botanist says, are "morphologically" leaves. This does not necessarily mean that at former evolutionary stages they were foliage leaves, but does mean that their manner of origin, their position with regard to other parts of the plant, as well as other characters, correspond to those of all leaf structures. Leaves arise from the outer tissues of the stem, and originate as slight lateral swellings (*primordia*) near the base of the growing point (*vegetative cone*) of the stem. They are developed in *acropetal succession,* that is, in regular order, the youngest always toward the apex of the stem. Moreover, they have a limited growth, i. e., develop to a certain size and then stop. There is no growing point, composed of cells capable of continual growth and division, as in stems and roots. Again, except in some instances, (e. g. Bryophyllum and Begonia) leaf structures do not produce buds, i. e., stems and leaves, nor roots. In many cases, but by no means all, buds develop at the leaf axils, i. e. on the stem just above the point of insertion of the leaf. We may sum up the characters of leaves as follows:

1. Borne on stems.
2. Originate from outer stem issues near the base of the growing point of the stem.
3. Develop in acropetal succession.
4. Have limited growth.
5. Do not produce buds or roots but *may* show buds in their axils.

I. TYPICAL FOLIAGE LEAVES

1. *Form.* The kind of leaf of most common occurrence in the higher plants is the "foliage" leaf, composed of three main parts; *blade,* the thin, green, flat, expanded portion; *petiole,* the stalk, extending from the base of the blade down to the stem of the plant; and *stipules,* a pair of leaf-like growths on opposite sides of the petiole and at its base. Petiole and stipules may be lacking, but the blade, in the case of foliage leaves, is nearly always present. Besides being flat, green, and thin, the blade is *dorsiventral,* i. e., the under surface differs from the upper. It is usually situated in a more or less horizontal position; i. e., perpendicular to the rays of light.

As to *venation,* i. e., the course taken by the veins in the blade, there are two principal kinds of arrangement; *parallel-veined,* where the larger veins, all of about equal size, run more or less parallel to each other, lengthwise of the blade, as in Orchids (Brooklyn Botanic Garden Conservatories, House 2), or branch from a central large vein (midrib) and then run parallel to each other, as in the Banana (center of House 5). The leaves of most monocotyledons (grass, sedge, lily, orchid families, etc., whose seeds have an embryo with only one seed leaf or cotyledon) are parallel-veined, with, however, some exceptions. House 8 in the Conservatories is devoted to tropical monocotyledons. In the outdoor plantations the monocotyledons will be found west of the brook and north of the Ecological garden. The other principal kind of venation is the *netted-veined,* where veins of unequal size form a network, the smaller veins or veinlets, especially, intersecting. The foliage leaves of the dicotyledons (plants with two seed leaves in the embryo, as in the bean, maple, etc.,) have netted-veined leaves. Good examples may be seen in Houses 3 and 4 as well as in the outdoor plantations. In addition to these two types of venation, another condition (called *uni-nerved*), is usual in needle-like leaves of the gymnosperms. Here only a single vein occurs, running lengthwise. (Pines, Spruces, etc. near the Lake).

With regard to the *shape of the blade* there are four main classes of foliage leaves; *orbicular* or approximately circular in outline, (East Indian Lotus, *Nelumbo nucifera,* in Lake; Nasturtium, Ecological garden); *ovate,* (Beech and Lilac in northwest part of Garden, Magnolia in triangular plot just west of Laboratory Building, and many others); *linear,* as in leaves of most grasses; and *needle-like* or *acicular* as in leaves of Heath, Pines, Spruces, etc. Between these principal forms there are many gradations; e. g. *obovate, cuneate* or wedge-shaped, *spatulate, lanceolate, oblanceolate, oblong, elliptical, oval,* etc.

As to the *outline* of the leaf margin, a great variety of forms exists, such as *entire,* where the margin is unbroken; *serrate,* with sharp teeth like a saw; *dentate,* or toothed; *undulate,* with a wavy margin; *sinuate*, with the undulations deeper (from *sinus*, a bay or gulf); *incised; lobed; cleft;* etc. These seem to have nothing to do with the leaf function, but are of great value in the description, and hence classification, of the various species of which they are characteristic. The base of the blade may be *cordate* or *heart-shaped, auriculate* or eared, *halberd-shaped*, etc. The apex, also, may be *acute, acuminate* or long-pointed, *obtuse, truncate, emarginate* or notched, *mucronate,* etc. These characters, also, are of great value in classification.

Finally, the blade may be undivided, in which case it is called *simple;* if divided into separate parts, called *leaflets,* it is said to be *compound.* In case the leaflets are attached along the sides of a central axis (*rhachis*), the leaves are called *pinnate,* (from Latin *pinna,* feather), or *pinnately compound* as in the common locust, just west of the Lily Pools. Where the leaflets are attached at a single point, the leaves are called *palmate,* (from Latin *palma,* palm of the hand) or *palmately compound,* as in the horsechestnut, which may be seen in the outdoor plantations, with the Horsechestnut Family, near the walk and southwest of the locusts.

2. *Functions.* When one considers the great variety of foliage leaves and their almost universal occurrence—that the greenness of vegetation is due to them and that they are one of the commonest sights of our everyday lives, it is one of the strangest facts of human existence that *comparatively few people know what a leaf is for.* This is the more remarkable when we couple with it the fact that our supply of food depends on the work of green leaves, so that without them, as things are at present constituted, the human race could not exist. For foliage leaves have the power of absorbing the very small amount of carbon dioxide (CO_2) that exists in ordinary air, and uniting it chemically with water, (H_2O), brought up to them through the veins from the roots, to form sugar, which may be later changed by the plant to starch. The foliage leaves, then, are primarily *sugar-making* organs.

The energy derived from light is used by the leaf to bring about this chemical combination of these two substances—CO_2 and H_2O—and the tiny green bodies (*chloroplasts*) in leaves have the power of using this energy, deriving it mainly from the red waves of light, although the blue-violet waves help a little. The other light waves—mainly green and yellow—are not needed, and hence are reflected.

This, then is the reason for the universal green color of vegetation, and this principal function of foliage leaves, i. e., sugar-making with the aid of light, is called *photosynthesis* (*photo*—light+*synthesis*—a putting together).

When we see a tree with perhaps thousands, or even hundreds of thousands of green leaves, we should think of it as it is—a living being, putting out this host of small organs, the leaves, somewhat as an octopus would put forth its tentacles—to get a supply of food. This is why the leaves are flat, so that they may be easily oriented in a plane suitable for receiving the rays of light to best advantage. They are thin, because, if thicker, the light would not penetrate beyond a certain point; they are green because this color represents the mixture of light waves not used in their chemical laboratories, and hence screened out or reflected.

Besides performing the function of photosynthesis, foliage leaves are important as organs of *transpiration,* i. e. in the giving off of water in the form of vapor; and in common with other parts of the plant they carry on *respiration.* Their ability to absorb CO_2 may also be classed as a special function.

II. FOLIAGE LEAVES WHICH HAVE ADDITIONAL FUNCTIONS

Here are classed those foliage leaves which, besides their regular work, have one or more additional functions.

a. For Storage of Water. The leaves of many plants (*xerophytes*) which live in dry regions, besides performing the function of food-making and the other functions named above, have taken on the added function of storage of water. In addition, many plants of the seashore and salt marshes (*halophytes*) have a similar leaf form—merely because in these regions fresh water is difficult to obtain.

A comprehensive collection of plants from desert regions of all quarters of the globe will be found in House 6 of the Conservatories. Conspicuous here are the Agaves or Century Plants on the further central bench. These are all natives of the dry table lands of Mexico, over 300 species being known. The Mesembryanthemums, known commonly as Fig Marigolds, in the southwest corner of the house, also illustrate water-storing leaves, which are here not so firm as in the Agaves and so are called "succulent." Over 300 kinds of these plants grow in the arid plains in South Africa.

b. For Catching and Holding Water. The leaf bases of many species of the Pineapple Family (Bromeliaceae, east bench of House 8) clasp the stem so tightly that water is retained in the cavity thus formed. In others (Billbergia) the leaves are arranged to form cylindrical tubes which serve this purpose. Since the great majority of these plants are air plants, i. e., growing on rocks and boulders, trunks of trees, or even telephone and telegraph wires, without this provision for catching and keeping a supply of rain water they would soon dry out. These plants have been called *"cistern epiphytes."*

c. For Storage of Food. The bulb scales of the hyacinth, filled with food to start the next year's hyacinth plant on its way in life, are the bases of foliage leaves, the upper parts of which wither away after having performed the function of photosynthesis.

d. Insectivorous Leaves. Here the leaves are formed in such a manner that insects are entrapped, their bodies being subsequently digested and absorbed by the plant as part of its food. The following may be seen at the Garden:

1. Pitcher Plant (*Sarracenia purpurea*), in which the blade is transformed into a pitcher holding water. Here insects are caught, drowned, and digested, and at the same time the green tissue performs photosynthesis. (House 2, southwest corner.)
2. The leaf of the Venus Fly Trap (*Dionaea muscipula*), a most interesting plant, native of South Carolina swamps, imprisons insects by suddenly folding together along the line of its midrib, as soon as they touch sensitive hairs on the leaf surface. In this plant the petiole is enlarged to help in the work of photosynthesis. (House 2, southwest corner.)

e. With Tendrils or Twisting Petioles for Climbing. Tendrils are slender, almost threadlike structures, which serve to attach the plant or part of it to a support. In members of the Pea Family (central part of outdoor plantations) one or more of the leaflets of each leaf may be transformed into tendrils. In many cases in this family the stipules are enlarged, and now do the chief part of the work of photosynthesis. Sometimes, as in Clematis (northern part of Crowfoot Family in outdoor plantations), the petiole, or leaf-stalk, is the part that twists around the support, thus enabling the plant to "hold on." Other examples of this last may be seen in House 3, where the twisting petioles assist the twining stems of the Pelican Flower (*Aristolochia grandiflora*), from South America. A similar condition obtains in the Calico Flower, (*Aristolochia elegans*), from Brazil, and is quite general in the Aristolochias. In the common Smilax or Greenbrier of our woods and fields (*Smilax rotundifolia*) and the less common species, *S. glauca,* the tendrils have been thought to be transformed stipules.

f. Developing Thorn-like Petioles for Clinging. An interesting case of a petiole which becomes, in part, a spine-like structure of advantage in helping the plant to climb, or rather to secure a firm hold on some support, is seen in the Rangoon Creeper (*Quisqualis indica*), a native of Malaya (House 5, near door of House 6). Here the petioles, after performing their normal function of holding the leaves outward, develop a joint about midway of their length, at which the outer portion, plus the leaf, fall off, leaving a short projection which becomes thornlike. Since the leaves are borne opposite each other, the result resembles a firemen's scaling ladder, where the steps are fastened to a single pole.

III. OTHER FORMS OF LEAF-LIKE NATURE OF ORIGIN

Here are classed all leaf forms which are not foliage leaves. In many cases they, too, may perform photosynthesis during a part or all of their existence.

a. Cotyledons. Also known as the "seed leaves," these are the first leaves of the embryo, and are generally much simpler in form than the later foliage leaves. They may be much thickened, serving as reservoirs of food for the young plant, which, without such assistance, would be helpless. They may remain below the ground during germination, as in the pea, horsechestnut, oak, etc., and are then called *hypogeal,* from *hypo*—under, and *ge*—earth; or they may be lifted up into the air, become green and help in the work of photosynthesis, and are then known as *epigeal,* from *epi*—upon, and *ge*—earth. Examples of this latter class are the common bean, castor bean, apple, etc.

b. Scale Leaves.

1. *Ordinary Scale Leaves.* On erect shoots, scale leaves often appear as precursors of foliage leaves, and hence may become green as in the Lily-of-the-Valley (*Convallaria majalis*) (west central part of Garden, near Flatbush Avenue). Scale leaves also occur regularly below the "eyes" or buds of potato tubers, although here they may be so much reduced as to be scarcely visible. They may be found on the rhizomes or underground stems of perennial grasses and other herbs, at the nodes; and in these instances, being pale, or without green color, are no longer functional. They may be seen at the bases of the green branches of Asparagus, the latter having taken over the function of food making, e. g. in *Asparagus plumosus,* south end of House 8. *Asparagus asparagoides,* also known as *Myrsiphyllum asparagoides,* from South Africa, and popularly called Smilax, but not really a true smilax, has similar scale leaves, the morphological representatives of the foliage leaves, at the bases of the leaf-like branches or cladophylls. The Butcher's Broom, (*Ruscus aculeatus*), from Europe (east bench in House 11) shows a similar condition. All scale leaves, including also most bud scales, are to be regarded as foliage leaves in an arrested state of development.

2. *Scale Leaves for Storage of Food.* The thick bulb scales of the lily are specialized, having taken on the function of storage of food.

3. *Bud Scales.* The winter buds of most of our woody plants are wrapped in protective scales, called bud scales, which are usually without green coloring and which in most cases represent the base of a foliage leaf, the blade remaining undeveloped; e. g. lilac, elm, horsechestnut, etc. All these bud scales belong in the category of scale leaves. Sometimes, however, as in the tulip tree and magnolia, the bud scales represent transformed stipules.

c. Bracts. These are small, leaf-like structures ordinarily appearing in the region of the flower. The "heads" of the dandelion and daisy flowers, for example, are subtended at the base by a large number of bracts (in this case green) called collectively the "involucre." Often, in flower clusters, one of these small leaves subtends each flower. In the latter case they have apparently no special function, but represent foliage leaves in an arrested state of development. But in the Linden the bract attached to the flower cluster serves as a sail so that the fruit may be carried by the wind some distance from the parent tree. Often bracts in the region of the flower are highly colored, thus taking on the function of attracting insects for cross pollination, the true flowers in these cases being usually inconspicuous. Examples are *Poinsettia* (Central or Economic House) and *Bougainvillea,* (House 3, east bench, and House 12, east bench). The four large, white bracts surrounding the central cluster of small flowers in the Flowering Dogwood (*Cornus florida*), are bud scales which develop into this showy form just before the flowers open.

d. Floral Leaves. The sepals, the outer green envelope of the typical flower, as well as the petals, the variously colored inner envelope, are morphologically leaves. The sepals, being green, assist in the work of photosynthesis as well as protecting the inner parts of the flower in the bud. The bright color of petals attract insects for cross pollination. Furthermore, stamens and carpels are also of leaf-like nature, being sporophylls, or spore-bearing leaves. Common flowers which show all these parts well are the buttercup and the wild rose. The evolution of the parts of the flower is discussed in a former LEAFLET (Series XI, No. 9. 1923).

e. Phyllodes. These forms are also cases where, as in most bud scales, the leaf blade has been suppressed in its development, but here the petiole has expanded and now takes on the function of photosynthesis. Good examples are seen in several species of Acacia, e. g. *Acacia melanoxylon,* on the east bench in House 12. Most interesting gradations may be seen here on the same plant, from compound leaves to phyllodes. Forms may be seen with tiny leaflets still persisting at the tip of the phyllode. In a case like that of the Acacias, whose hereditary leaf form is much divided, these plants are obviously much better adapted to a life in dry regions by forming this leaf-like, flattened petiole—usually extending in a more or less vertical plane with respect to the ground—than by exposing numerous small leaflets to the intense sunlight. Splendid examples of phyllodes may also be seen in *Oxalis bupleurifolia,* from Brazil, at the north end of the east bench in House 4.

f. Spines. Cases of the transformation of the leaf blade into a spine or spines are seen in the Barberries, where the 3-pronged spine (*Berberis vulgaris,* outdoor plantations) may be regarded as evidence that the leaf of the ancient barberries was compound. In the Japanese Barberry, (*B. Thunbergi*), the evolution has gone further, for here the spines are simple. The fact that buds and branches arise in the axils of these spines proves their leaf-like nature. The huge, twin thorns of the Bull's Horn Thorn (*Acacia sphaerocephala*), from Mexico (House 3, central bench) are obviously of stipular origin. The same is true of the paired spines in the Common Locust (*Robinia pseudoacacia*) west of the lily pools. The thorns of the cacti, e. g., species of Opuntia, are, in many cases at least, the morphological equivalent of leaves. Here the flattened, leaf-like stem carries on the work of photosynthesis.

SUMMARY

I. TYPICAL FOLIAGE LEAVES

1. *Form.* Various, but typically thin and dorsiventral.
2. *Functions.* Mainly for photosynthesis, but also perform transpiration, respiration, and absorb CO_2 from air.

II. FOLIAGE LEAVES WHICH HAVE ADDITIONAL FUNCTIONS

a. For Storage of Water

Agaves, Mesembryanthemums, etc., House 6.

b. For Catching and Holding Water.

Lvs. with clasping bases or otherwise arranged to hold water. Members of Pineapple Family. House 8.

c. For Storage of Food.

Fleshy bases of hyacinth lvs.

d. Insectivorous Leaves.

Pitcher Plant, *Sarracenia purpurea,* House 2. Venus Flytrap, *Dionaea muscipula,* House 2.

e. With Tendrils or Twisting Petioles for Climbing.

Leaflets transformed into tendrils.
  Members of Pea Family, outdoor plantations.
Petiole twines about support.
  Clematis, outdoor plantations.
  Pelican Flower and other Aristolochias, House 3.
Stipules transformed into tendrils.
  Greenbrier, *Smilax rotundifolia,* and *S. glauca* of our woods and fields.

f. Developing Thorn-like Petioles for Clinging.

Rangoon Creeper, *Quisqualis indica.* House 5.

g. With Petioles Serving as Floats.

Water Hyacinth, *Eichornia crassipes,* House 2.

III. OTHER FORMS OF LEAF-LIKE NATURE OR ORIGIN

a. Cotyledons.

b. Scale Leaves.

1. Ordinary Scale Leaves.

Precursors of foliage lvs., as in Lily-of-the-Valley, west central part of outdoor plantations. Also on potato tubers, and underground stems of perennials. At bases of green branches of Asparagus, House 8, and also in same position in "Florist's Smilax," *Asparagus asparagoides.* Likewise in Butcher's Broom, *Ruscus aculeatus,* House 11.

2. Scale Leaves for Storage of Food.

Bulb scales of lily.

3. Bud Scales.

Winter buds of most woody plants, as lilac, elm, horsechestnut, etc. (outdoor plantations).

c. Bracts.

Flower heads of dandelion, daisy, etc.
Flower heads of flowering dogwood. Outdoor plantations.
Flowers of Poinsettia, House 5, and of Bougainvillea, Houses 3 and 12.
Sail-like bracts of linden, (Tilia). Outdoor plantations.

d. Floral Leaves.

Sepals, petals, and sporophylls (stamens and carpels) of flowers.

e. Phyllodes.

Acacia melanoxylon and other species. House 12.
Oxalis bupleurifolia. House 4.

f. Spines.

Leaf blade transformed to simple or branched spine. Barberries in outdoor plantations: Opuntia, etc., House 6.
Stipules transformed to thorns.
  Bull's Horn Thorn, *Acacia sphaerocephala,* House 3.
  Black Locust, *Robinia pseudoacacia.* Outdoor plantations.

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